and Kohala, had only from 5 to 50 per cent of the normal rainfall; southeast and southwest exposures on the same island had from 200 to 400 per cent of normal; the same excess occurred on Kauai Island, and the same abnormal distribution on Maui Island. Extremes of precipitation, 0.07 at Niulii, north Kohala, and 28.75 at Wahiawi, Mount Kauai. There was an unusual excess of southerly airs and lack of trade wind, which accounts for the abnormal distribution of rainfall.

Meteorological Observations at Honolulu, May, 1901.

The station is at 21° 18′ N., 157° 50′ W.

Hawaiian standard time is 10h 30m slow of Greenwich time. Honolulu local mean time is 10h 31m slow of Greenwich.

Pressure is corrected for temperature and reduced to sea level, and the gravity correction, —0.06, has been applied.

The average direction and force of the wind and the average cloudiness for the whole day are given unless they have varied more than usual, in which case the extremes are given. The scale of wind force is 0 to 12, or Beaufort scale. Two directions of wind, or values of wind force, or amounts of cloudiness, connected by a dash, indicate change from one to the other.

The rainfall for twenty-four hours is measured at 9 a. m. local, or 7.31 p. m., Greenwich time, on the respective dates.

The rain gage, 8 inches in diameter, is 1 foot above ground. Thermometer, 9 feet above ground. Ground is 43 feet, and the barometer 50 feet above sea level.

Date.	Pressure at sea level.	Temperature.		During twenty-four hours preceding 1 p. m. Greenwich time, or 2:30 a. m. Honolulu time.									Total rainfall at 9 a. m., local time.
				Temperature.		Moisture.		Wind.		Average cloudiness.	Sea-level pressures.		
		Dry bulb.	Wet bulb.	Maximum.	Minimum.	Dew-point.	Relative humidity.	Prevailing direction.	Force.		Maximum.	Minimum.	
	*	†	†			‡	‡		§				
1	30.00	67	66	84	67	66.0	81	s-n.	1-0	6	30.06	29.97	0.08
2	29.98	69	67.7	81	66	67.7	81	sw-n.	1	6	30.06	29.97	0.02
3	29.95	70	69.3	81	67	68.3	83	se-n.	1	5	30.02	29.94	0.08
4	29.96	71	69.7	81	70	69.5	85	se-sw.	1	6	30.00	29.91	0.06
5	30.05	70	68	81	68	69.3	85	sw.	1	6	30.06	29.95	0.05
6	30.05	68	67.3	81	67	68.7	88	s-n.	1-0	2-10	30.08	30.04	1.03
7	29.99	67	66.3	81	67	69.0	85	e.	1-0	6	30.06	29.99	0.30
8	29.91	67	66.3	81	66	67.7	85	se.	1-0	6	30.02	29.92	0.07
9	29.90	66	65.3	79	66	67.5	86	se.	1-0	6-0	29.94	29.89	0.45
10	29.95	67	65.7	82	64	68.7	87	sw.	1-0	0-8	29.97	29.89	0.00
11	30.02	68	67	84	65	66.5	76	nne.	1	1	30.05	29.94	0.00
12	30.06	70	68	84	67	66.3	73	nne.	2	1-0	29.11	29.99	0.00
13	30.02	73	68.5	84	68	67.5	75	ne.	2	2	30.09	30.02	0.00
14	29.95	73	68.5	83	70	66.7	74	ne.	2	3-0	30.06	29.96	0.00
15	29.96	69	67	83	68	66.5	72	ne.	3-0	4-1	30.01	29.92	0.00
16	29.99	75	69.5	83	67	66.0	71	ne.	3-1	3	30.07	29.96	0.00
17	29.98	75	68.5	82	73	67.5	73	ne.	3	5	30.07	30.00	0.07
18	29.98	76	69.5	82	74	66.3	69	ne.	3-5	4	30.06	30.00	0.01
19	29.94	76	70.5	83	74	67.3	70	ene.	4	4	30.00	29.95	0.05
20	29.92	74	69.5	83	72	67.0	69	ne.	3-4	2-6	29.96	29.90	0.00
21	29.96	69	67.7	84	74	67.7	72	ne.	3	3	29.98	29.93	0.00
22	29.95	69	67	83	69	68.7	80	se-n.	2	3-8	30.02	29.95	0.10
23	29.88	73	68	82	68	67.0	76	nne.	3	3	29.96	29.88	0.00
24	29.94	74	68	84	67	67.7	76	se-nne.	2-0	3-7	29.96	29.86	0.09
25	20.98	73	68	83	67	65.3	68	ene.	2-0	5	30.02	29.94	0.07
26	30.00	75	68.5	84	67	65.7	67	se-ne.	2-4	3	30.05	29.99	0.00
27	29.98	74	68.5	83	74	65.5	64	ene.	4-2	4	30.08	29.99	0.01
28	29.92	71	69	84	72	66.7	70	ene.	3-0	4	30.00	29.92	0.09
29	29.88	71	70	81	70	68.3	82	esw.	1-0	8-3	29.95	29.88	0.37
30	29.91	72	70.7	81	69	70.3	84	ssw.	1-3	7	29.95	29.86	0.06
31	29.95	71	68.5	81	70	70.7	83	ssw.	1-0	8-2	29.99	29.93	0.27
Sums	......	......	......	......	......	......	......	......	......	......	......	......	3.23
Means	29.965	71.1	67.6	82.3	68.8	77.0	77.1	......	1.7	4.0	30.022	29.943	......
Departure	—.042	......	+3.7	......	......	+6.7	......	......	......	—0.4	......	......	......

Mean temperature for May, 1901 (6 + 2 + 9) ÷ 3 = 74.8; normal is 74.2. Mean pressure for May, 1901 (9 + 3) ÷ 2 = 29.979; normal is 30.021.

*This pressure is as recorded at 1 p. m., Greenwich time. †These temperatures are observed at 6 a. m., local, or 4:31 p. m., Greenwich time. ‡These values are the means of (6 + 9 + 2 + 9) ÷ 4. §Beaufort scale.

SUMMARY OF METEOROLOGICAL RECORD FOR THE MONTH OF MAY, 1901, AT HONOLULU (PUNAHOU.)

Temperature: mean for the month, 74.8°; normal, 74.2°; average daily maximum, 82.3°; average daily minimum, 68.8°; average daily range, 13.5°; greatest daily range, 19°; least daily range, 8°; highest temperature, 84°; lowest, 64°.

Barometer: average, 29.979; normal, 30.021 (corrected for gravity by —.06); highest, 30.11; lowest, 29.86; greatest 24-hour change, 0.9. Lows passed this point on the 8th, 19th, 23d, and 29th; highs on the 5th, 11th, 17th, and 25th. There were no very marked changes in pressure.

Relative humidity: average, 79; normal, 70; mean dew point, 67.6; normal, 64; mean absolute moisture, 7.38 grains to the cubic foot; normal, 6.53. The humidity was considerably the highest of any month of May on record for twelve years.

Rainfall: 3.23 inches; normal, 3 inches; rain-record days, 20; normal, 19; greatest rainfall in one day, 1.03 on the 6th; total at Luakaha, 13.57; at Kapiolani Park, —. Total rainfall since January 1, 21.52; normal, 17.30.

The artesian well utilized for observation at Punahou is closed for repairs; consequently there is no record for this month.

Trade wind days: 16 (3 of north-northeast); normal number of trade wind days for May, 24; average force of wind, 1.7, Beaufort scale; cloudiness, tenths of sky, 4.0; normal, 4.4.

Approximate percentage of district rainfall as compared with normal: Hilo, 40 per cent; Hamakua, 12; Kohala, 12; Waimea, 66; Kona, 210; Kau, 200; Puna, 75; Maui, north exposures, 100 per cent, southeast exposures, 200; Oahu, normal, excepting Koolaupoko, 150; Kauai, 250 per cent, excepting Hanalei, north coast, 100. The cause of the abnormal distribution of rain was the excess of southeast wind above normal, causing precipitation on the corresponding exposed side of the higher islands.

Average temperatures: Pepeekeo, Hilo district, 100 feet elevation, average maximum, 78°; average minimum, 68°; Waimea, Hawaii, 2,730 feet elevation, 77° and 64.3°; Kohala, 521 feet elevation, 82.5° and 70.3°; Kulaokahua, W. R. Castle, Oahu, 60 feet elevation, highest, 86°; lowest, 67°.

No earthquake reported this month. Snow is still visible on the summit of Mauna Kea.

There was thunder at Honolulu on the 8th and 9th.

MEXICAN CLIMATOLOGICAL DATA.

Through the kind cooperation of Señor Manuel E. Pastrana, Director of the Central Meteorologic-Magnetic Observatory, the monthly summaries of Mexican data are now communicated in manuscript, in advance of their publication in the Boletin Mensual. An abstract, translated into English measures, is here given, in continuation of the similar tables published in the MONTHLY WEATHER REVIEW since 1896. The barometric means are now reduced to standard gravity.

Mexican data for May, 1901.

Stations.	Altitude.	Mean barometer.*	Temperature.			Relative humidity.	Precipitation.	Prevailing direction.	
			Max.	Min.	Mean.			Wind.	Cloud.
	Feet.	*Inch.*	°F.	°F.	°F.	%	*Inch.*		
Culiacan (Sin.)	112	29.67	95.0	67.8	80.1	49	0.29	sw.	....
Leon (Guanajuato)	5,906	24.21	92.1	49.5	73.9	23	0.01	nw.	w.
Linares (Nuevo Leon)	1,188	28.50	100.4	60.8	78.6	75	4.25	s.	s.
Mazatlan	25	29.84	83.3	65.8	75.0	75	......	nw.	w.
Mexico (Obs. Cent.)	7,472	22.97	86.7	47.8	67.1	49	0.63	se., sw.	ne.
Morelia (Seminario)	6,401	23.89	85.3	50.5	68.7	55	0.70	sw.	w.
Puebla (Col. Cat.)	7,125	23.29	83.7	48.0	69.8	56	1.98	e.	wsw.
Saltillo (Col. S. Juan)	5,399	24 67	91.4	51.8	71.8	63	0.47	s.	s.
S. Isidro (Hac. de Gto)	......	......	82.4	65.8	......	......	0.08	w.	....
San Luis Potosi	6,202	24.01	94.3	51.1	73.6	46	0.64	e.	w.
Toluca	8,812	21.91	80.6	39.2	60.8	48	1.73	w.	e.
Zapotlan (Seminario)	5,079	25.00	93.2	51.8	73.6	50	0.02	sse.	w.

*Reduced to standard temperature and gravity.

TWENTY YEARS' STUDY OF SNOW CRYSTALS.

By W. A. BENTLEY, of Nashville, Vt., April 13, 1901.

During the winter of 1884 the writer secured his first microphotographs of snow crystals; previous to this he had made some 300 drawings but found these unsatisfactory.

Photographs have been secured during every winter since

1884 and they now number over 800, no two alike. Nearly every great and famous winter storm since that date has furnished its quota of from four to twenty (and in one instance thirty-four) of new forms to this collection. At the same time observations have been made and data secured, while photographing them, of the temperature; kinds and approximate heights of clouds (when possible); the direction and rapidity of movement of various cloud strata; the direction and velocity of the surface winds; also changes in the forms of the crystals from hour to hour as the different portions of each storm passed over our locality. The latter observations were made to ascertain whether there was any general law of distribution of the forms within the different portions of a storm. Differences in form of crystals deposited by local storms from those of general storms were also noted, as also the forms originating in, and peculiar to, each of the various cloud strata. These observations, and the data secured, indicate that the temperature and the humidity of the air at the earth's surface is a much less important factor than is generally supposed in determining the form and size of the crystals. We may easily conceive this to be the case, because at a given temperature, etc., at the earth's surface, the temperature and humidity of the air where the crystals form might vary greatly, one time from another, and would depend largely upon the height of the snow-producing clouds. The height of these varies greatly at different times, even when the temperature at the earth's surface remains the same. The data secured has not revealed the great mystery of the origin and cause of the differences in the forms of the nuclei; why columnar forms predominate at one time, tabular forms at another, or why both are sometimes found associated together. Much has been learned, however, of the conditions tending to modify their forms after the nuclear form is once organized. These conditions are many, the chief among them being the height, number, and vertical depth of the cloud strata and the resultant variation in temperature, atmospheric pressure, and humidity due to these; the character of the storm, whether local or general, and the portion of the storm region from which the crystals come. To these must also be added the initial and subsequent movement of the crystals within the clouds. If, as must often be the case, the nuclear forms originating in the lower ascending clouds are carried upward to much greater heights by the strong ascending air currents, which often occur within such storms, until they become heavy enough to fall back through them, then the crystals will in all probability be greatly modified by passing through atmospheric strata varying so greatly in density, temperature, humidity, etc. That they are greatly modified by these flights in the clouds is clearly shown by the interior structure of many of the crystals outlining many of these transitory states. Thus, crystals whose nuclear form was originally nearly perfectly hexagonal, sometimes become partly triangular in outline, and vice versa. No. 19 is an example of such modifications.

Nuclear imperfections are often corrected and crystals become perfect in form, as in No. 8. Conversely, perfect crystals become imperfect, as in No. 18.

Tabular outgrowths in rare instances take place around a prismatic crystal, while spinous outgrowths often occur from and on a perpendicular with the main axis of tabular crystals.

Crystallization sometimes goes on also around the parts of a broken crystal, as in the very interesting example, No. 23.

Small tabular hexagons often acquire branching additions around their angles in the lower clouds and become of large size, as in Nos. 16, 7, 8, 11, 15.

Again, perfect crystals often receive additions of granular material in the lower clouds.

Perhaps the most important facts of a general nature to be gleaned from our twenty years' study are these:

1. That the greater number of the more perfect and beautiful tabular forms occur much more frequently in and are confined almost wholly to the western and northwestern portions of great storms and blizzards.

3. That there seems to be a law of general distribution of the different forms, the columnar to one, the tabular and granular to others, with many varieties associated together in other portions of such great storms.

3. That this distribution is, with few exceptions, constant, that is, the same in nearly all storms.

Sufficient data has not as yet been collected to demonstrate beyond all doubt the fact that this law applies to all forms of crystals and to all storms alike.

Passing on to the variation in form of those crystals deposited by local storms, as compared with those of general storms, we find that these are very marked, except during intense cold.

The local storm types and those precipitated from low, detached clouds usually consist of large, frail, branching, tabular forms, devoid of a solid tabular nucleus (see No. 24), or of heavy granular varieties, similar one to the other, each according to its class. On the other hand, those deposited by general storms are usually more diversified in form and more complex in structure, the snowfall often consisting of two or more varieties associated together. The larger and more perfect columnar prisms (similar to No. 26), columnar forms possessing tabular outgrowths at one or both ends (which we might call doublets), truncated triangular forms (see Nos. 2 and 3), and solid tabular forms, the latter often possessing wonderfully beautiful and complex interior designs (as in Nos. 1, 2, 3, 4), are common only to general storms. Branching tabular and granular forms are common to both general and local storms, but they ordinarily possess solid nuclei if deposited from a general storm (as in Nos. 5 to 16), whereas the nuclei are generally absent (as in No. 24) if the crystals originated in local storms. During zero weather the crystals of local storms approach much nearer in form to those of general storms, and we find solid tabular forms, branching tabular forms possessing solid hexagonal nuclei and sometimes doublets, among the snowfall. Often during the intense cold succeeding a blizzard the snowfall will consist wholly of very minute columnar and pyramidal forms, like No. 25, or of both columnar and minute frost like tabular forms, falling apparently from low, detached nimbus or alto-nimbus clouds, or even from a sky free, or nearly so, of clouds.

During relatively mild temperatures each cloud stratum, if alone, there being no other clouds either above or below them, commonly precipitates each its own peculiar type of crystals. Low detached nimbus clouds deposit large, frail, branching tabular forms, similar to No. 24; intermediate clouds, smaller, branching tabular forms, possessing solid hexagonal nuclei; and the high cirro-stratus clouds, small compact columnar and tabular forms. The large cumulus clouds of spring and autumn usually shed large, heavy, pyramidal-shaped granular snow. These granular forms frequently, if not invariably, possess nuclei of branching, tabular forms, and are usually precipitated when the temperature is near or somewhat above the freezing point.

Consulting the microphotographs engraved for this article, we find that, with the exception of No. 24, all are those common to and were deposited by great storms. The beautiful set of six forms, Nos. 11 to 17, photographed during the afternoon of February 13, 1901, possesses great interest, because they demonstrate that crystals of large size are not rare even during extreme cold. The forms of that date were unusually large and thick, yet the temperature was uncommonly low, 3° F. below zero to 3° F. above. The clouds from which they separated consisted of a rather thin stratum of intermediate clouds, lying at an altitude somewhat above 5,000 feet. A fresh west wind was blowing at this time, and clouds were drifting from west to east quite swiftly.

Further analysis of the forms of February 13 shows us that the crystals, while large and branching in outline, are not frail and ethereal like the branching forms common to mild temperatures. So broad are the secondary rays, it is obvious that a slight augmentation of growth would have filled in all the smaller interstices between the secondary and primary rays and greatly increased the dimensions of the solid nuclear portion. Further analysis reveals that the crystals have undergone a multitude of transformations, leaving the crystals full of interior details. This is a common characteristic of those produced during intense cold. By this we may conclude that during intense cold the outgrowths, while they may be many, are each of small extent.

Of the other numbers of the series, No. 2 is very rare and unusual, containing as it does eleven triangular divisions within its outlines. Apparently the lines of greatest growth were reversed during one stage of the growth of this strange form, thus differing widely from No. 3, whose outlines are somewhat similar. No. 6 possesses a very rare unique nuclear design which is very difficult to explain by any process of crystallization of which we know. No. 7 (a souvenir of the great blizzard of March 12, 1888) is very symmetrical, as also are Nos. 9 and 21, of February 15, 1901. No. 10 is, in all but the unimportant outermost points, a marvel of complexity and perfect symmetry. No. 20 is also a marvellously beautiful and symmetrical example of snow architecture. No. 22 is rare and unusual, a conundrum for the crystalographer.

Passing to the causes governing the formation of the nucleus, whether it be columnar or tabular, the electrified state of the atmosphere, whether negative or positive, and perhaps, also, as suggested by Prof. Cleveland Abbe, the presence in greater or less amounts of various gases and vapors in the atmosphere, may all be controlling factors.

The study of hoar frost crystals, which are also divisible like snow into two fundamental classes, columnar and tabular, may throw much light upon this obscure point. As already noted (see article on frost crystals in Popular Science, April, 1899), the two varieties of frost crystals do not usually coalesce in equal numbers; generally one or the other variety will greatly predominate and form the great mass of the crystals. Should it be found that one variety forms on nights when the air is negatively, and the others when it is positively, electrified, then we should be led to conclude that one is the negative and the other the positive form of crystal.

Although much has been already learned about these interesting phenomena, yet there still remains much more. Cooperation between many observers is essential to carry out this work successfully. Simultaneous observations of the forms and changes the crystals undergo from hour to hour during our great blizzards should be made by many skilled observers, stationed along a general line extending north and south. These observers must be familiar with the names and approximate heights of the various clouds. This study should include observations of the kind and approximate height and direction of drift of the various clouds, direction and force of the surface wind, temperature of the air, and amount of moisture at the earth's surface; also its electric condition, whether negative or positive, and the portion of the storm from which the crystals emanate.

It is also highly desirable that observations be made to ascertain why the perfect crystals are more common in the western portion of storms, and also why certain portions produce certain types.

Such a study, supplemented by investigations as to the causes of the formation of the two fundamental types of hoar frost crystals, would doubtless lead to the discovery of very many of the mysteries surrounding the origin and history of the wondrously beautiful forms of snow.

LIST OF MICROPHOTOGRAPHS ON PLATES I, II, AND III.

1. 1895, February 8. Wind northwest, temperature —4° F.
2. 1900, February 18. Wind west to northwest, temperature 11°.
3. 1899, February 13. Wind north, temperature 1°.
4. 1895, March 2. Wind northwest, temperature 16°. Cloud, cirro-stratus.
5. 1898, November 27. A great blizzard. Temperature 12°; size one-fifth of an inch.
6. 1900, December 5. Wind northwest to north. Temperature 22°. Cloud, stratus.
7. 1888, March 12. Great blizzard. Temperature 12°. Diameter one-quarter of an inch.
8. 1901, January 28. Wind changing from west to northwest. Temperature 11°.
9. 1901, February 15. Wind northwest. Temperature 14.
10. 1898, January 26. Wind changing west to northwest. Temperature 18°.
11. 1901, February 13.
12. 1901, February 13.
13. 1901, February 13.
14. 1901, February 13.
15. 1901, February 13. Temperature —2°. Diameter one-third of an inch.
16. 1901, February 13.
17. ——.
18. ——.
19. 1899, January 6. Wind south-southeast. Temperature 22°. Clouds, upper stratus.
20. 1886, February 26. Wind northwest. Temperature 8°.
21. 1901, February 15. Wind northwest. Temperature 13°.
22. 1900, December 27. Temperature 28°.
23. 1901, February 5. Temperature 18°.
24. ——. Wind west. Temperature 34°.
25. ——. Wind northwest. Temperature —11°. Thin, low clouds.
26. ——. Temperature 24°. Cirro-stratus clouds.

CLIMATOLOGICAL DATA FOR JAMAICA.

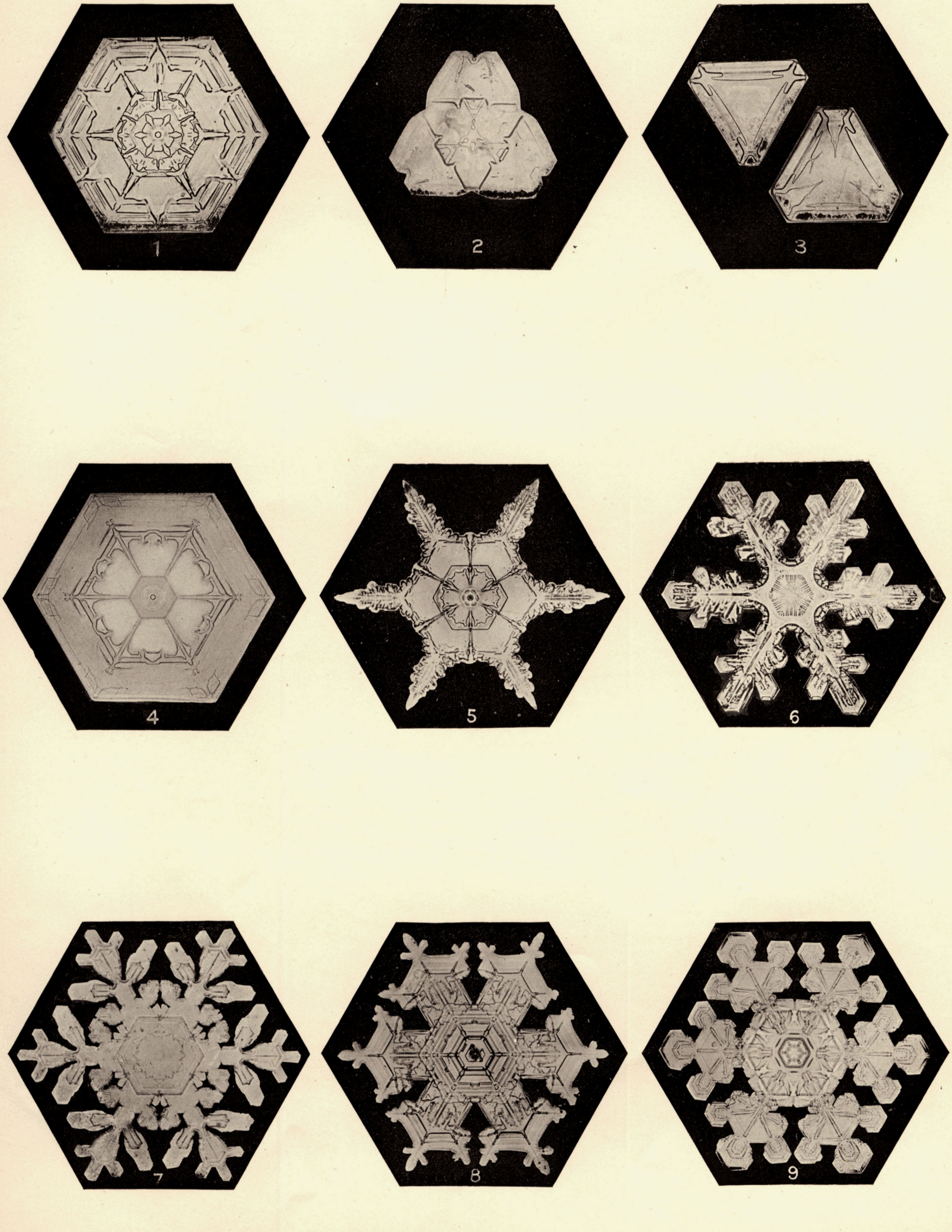
Through the kindness of Mr. Maxwell Hall, the following data are offered to the MONTHLY WEATHER REVIEW in advance of the publication of the regular monthly weather report for Jamaica:

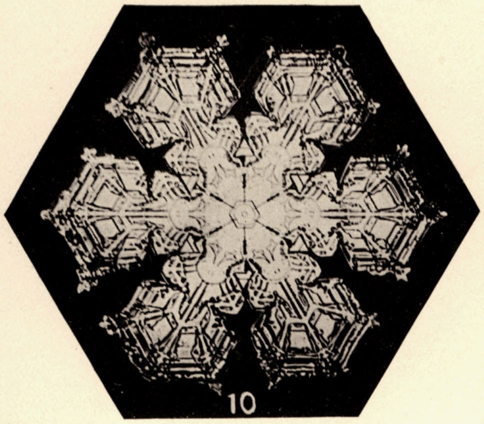
Jamaica, W. I., climatological data, May, 1901.

	Negril Point Lighthouse.	Morant Point Lighthouse.
Latitude (north)	18° 16′	17° 56′
Longitude (west)	78° 23′	76° 10′
Elevation (feet)	33	8
Mean barometer, 7 a. m.	29.904	29.902
Mean barometer, 3 p. m.	29.856	29.853
Mean temperature, 7 a. m.	80.3	80.6
Mean temperature, 3 p. m.	84.3	86.0
Mean of maxima	86.6	....
Mean of minima	74.3	....
Highest maximum	89.1	....
Lowest minimum	71.3	....
Mean dew-point, 7 a. m.	72.1	....
Mean dew-point, 3 p. m.	75.0	....
Mean relative humidity, 7 a. m.	74.5	....
Mean relative humidity, 3 p. m.	72.0	....
Total rainfall (inches)	1.71	3.49
Average wind direction, 7 a. m.	e.	e.
Average wind direction, 3 p. m.	....	se.
Average hourly velocity, 7 a. m.	6.7	6
Average hourly velocity, 3 p. m.	13.5	9.2
Average cloudiness (tenths):		
7 a. m. Lower clouds	0.0	1.3
7 a. m. Middle clouds	2.4	2.1
7 a. m. Upper clouds	3.3	1.2
3 p. m. Lower clouds	0.3	1.7
3 p. m. Middle clouds	6.5	2.2
3 p. m. Upper clouds	1.1	1.3

NOTE.—The pressures are reduced to standard temperature and gravity, to the Kew standard, and to mean sea level. The thermometers are exposed in Stevenson screens.

Microphotographs of Snow Crystals.

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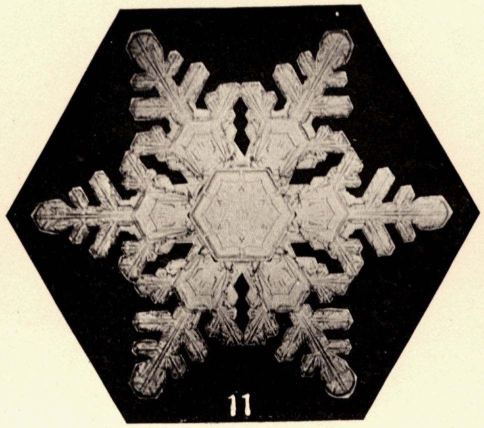
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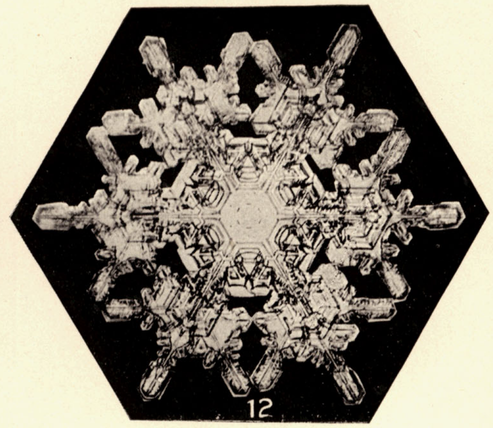
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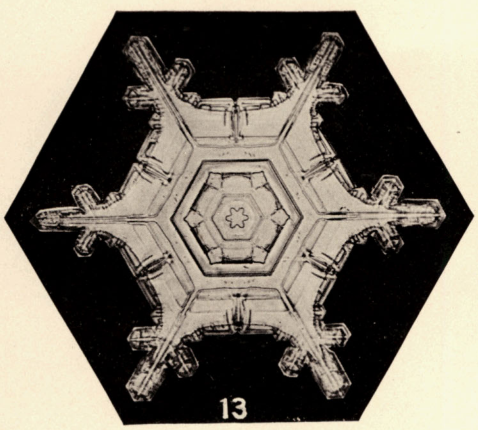
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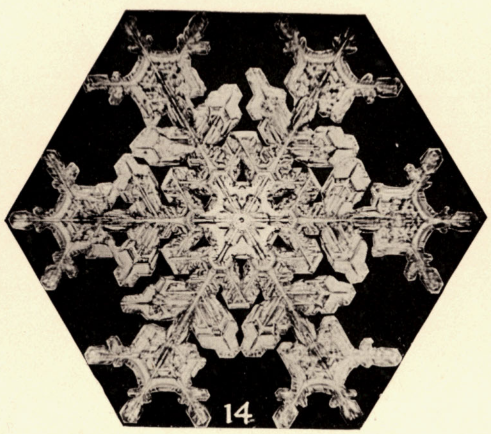
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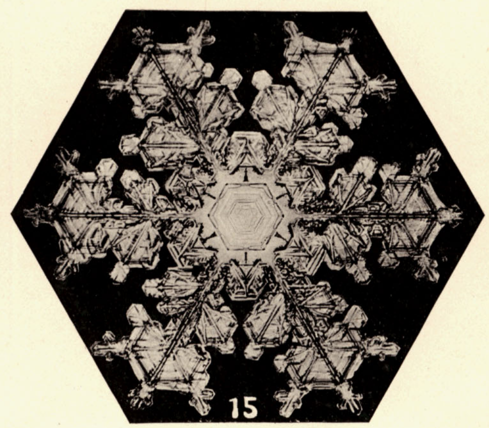
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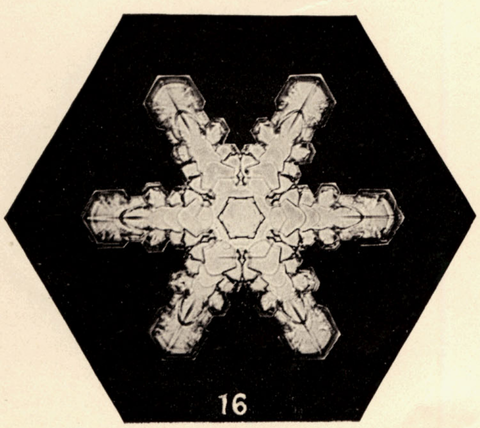
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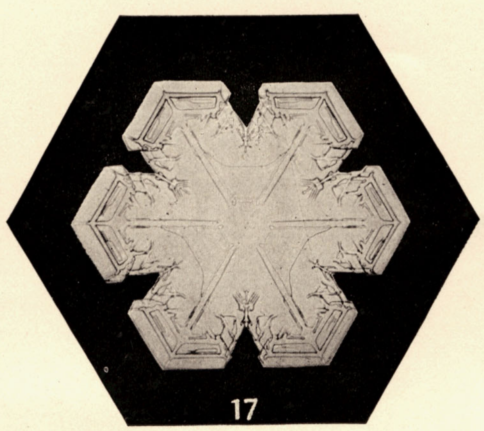
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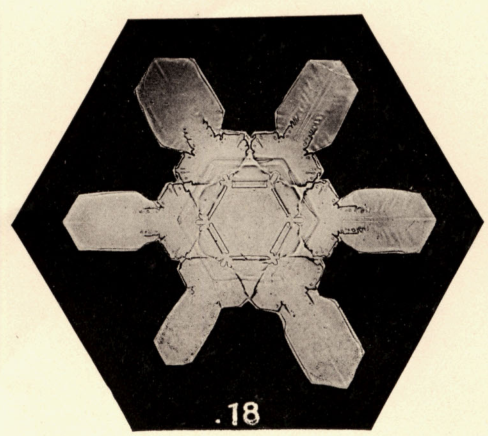
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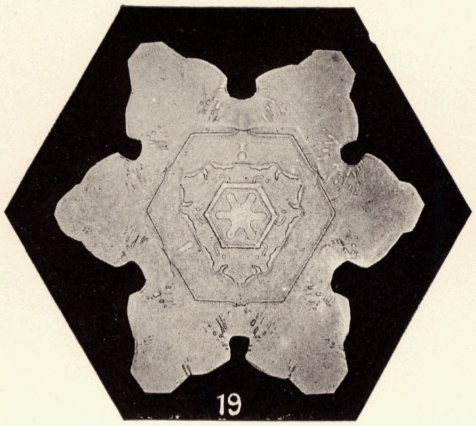

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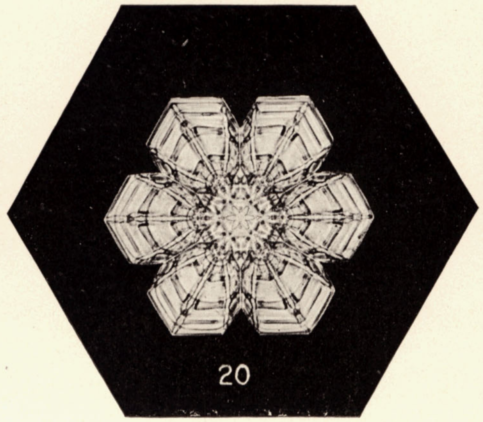

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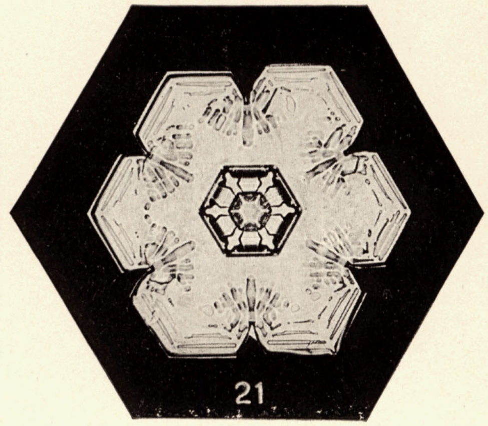

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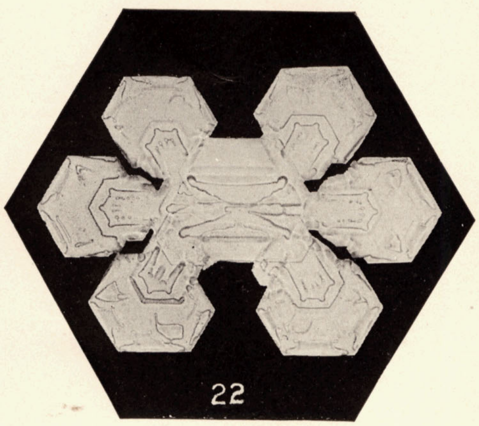

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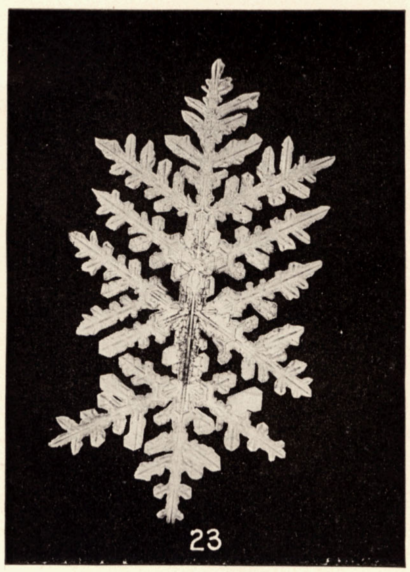

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